routine work in connection with the maintenance of the system of colonial time signals; a number of observations of the zenith distances of northern stars and circumpolars both above and below the Pole, for the comparison of declinations as observed at Observatories on either side of the equator; and some progress as having been made in the observation of pairs of equi-zenith distance stars for the determination of the latitude of the Observatory. The various computations undertaken at the Observatory have been pushed forward much more zealously. These embrace the comparison of the Greenwich lunar observations for the decade 1878-87 with Hansen's lunar tables; the reduction of Mr. Campbell's observations of the lunar crater Murchison A, made at the Arkley Observatory in the years 1882-84; and the reduction of the third year's tidal observations at Durban.

THE SPECTRUM OF R ANDROMEDÆ.—Mr. Espin, who has recently discovered bright lines in the spectra of several long-period variables of Secchi's third type, has added another to the list; R Andromedæ, at the maximum just passed, showing a number of bright lines, F being very bright, so bright as to appear to project beyond the spectrum. The spectrum of the star had manifestly undergone a great change from the time when Dunér made the very thorough study of it which he has recorded in his work on "Les Étoiles à Spectres de la Troisième Classe." Five of the seven variables included in Mr. Lockyer's Species 10 of this type have now shown bright lines at maximum, whilst Gore's Nova Orionis, which should certainly be included in the same species, would make a sixth. The two stars in which bright lines have not yet been observed are R Leonis Minoris and α Herculis.

COMET 1889 *d* (BROOKS, JULY 6).—The following ephemeris is in continuation of that given in NATURE for October 3 (p. 550):—

Ephemeris for Berlin Midnight.

1889.	R.A. h. m. s.	Decl. ° ′	Log *r*.	Log Δ.	Brightness.
Nov. 1	23 41 40	2 32·2 S.	0·2977	0·0625	1·8
5	23 42 56	2 3·6	0·2988	0·0754	1·7
9	53 44 39	1 33·1	0·3001	0·0888	1·6
13	23 46 49	1 0·8	0·3015	0·1025	1·5
17	23 49 25	0 27·0 S.	0·3030	0·1163	1·4
21	23 52 25	0 8·4 N.	0·3046	0·1303	1·3
25	23 55 49	0 45·2	0·3063	0·1445	1·2
29	23 59 34	1 23·3 N.	0·3082	0·1587	1 1

The brightness at discovery is taken as unity.

ASTRONOMICAL PHENOMENA FOR THE WEEK 1889 NOVEMBER 3-9.

(FOR the reckoning of time the civil day, commencing at Greenwich mean midnight, counting the hours on to 24, is here employed.)

At Greenwich on November 3

Sun rises, 7h. 0m.; souths, 11h. 43m. 40·4s.; daily increase of southing, 0·5s.; sets, 16h. 28m.: right asc. on meridian, 14h. 35·4m.; decl. 15° 13′ S. Sidereal Time at Sunset, 19h. 21m.

Moon (Full on November 7, 16h.) rises, 15h. 30m.; souths, 21h. 1m.; sets, 2h. 45m.*: right asc. on meridian, 23h. 54·5m.; decl. 6° 7′ S.

Planet.	Rises. h. m.	Souths. h. m.	Sets. h. m.	Right asc. and declination on meridian. h. m.	° ′
Mercury..	5 8	10 37	16 6	13 28·3	6 53 S.
Venus ...	4 29	10 9	15 49	13 0·0	4 37 S.
Mars ...	2 35	8 54	15 13	11 45·3	3 5 N.
Jupiter ...	11 38	15 31	19 24	18 23·6	23 27 S.
Saturn ...	0 22	7 28	14 34	10 19·5	11 53 N.
Uranus ...	5 16	10 36	15 56	13 28·0	8 37 S.
Neptune..	17 30*	1 18	9 6	4 8·4	19 15 N.

* Indicates that the rising is that of the preceding evening and the setting that of the following morning.

Saturn, November 3.—Outer major axis of outer ring = 39″·3; outer minor axis of outer ring = 5″·8: southern surface visible.

Meteor-Showers.

	R.A.	Decl.	
Near γ Camelopardalis...	55°	71° N.	Swift.
,, the *Pleiades*	60	20 N.	The *Taurids*.
,, θ Ursæ Majoris ...	143	50 N.	Very swift.
From Lacerta...	346	52 N.	Rather slow.

Variable Stars.

Star.	R.A. h. m.	Decl. ° ′		h. m.	
U Cephei	0 52·5	81 17 N.	Nov. 4,	1 23	*m*
			,, 9,	1 3	*m*
R Canis Majoris ...	7 14·5	16 11 N.	,, 6,	17 5	*m*
			,, 7,	20 20	*m*
S Cancri	8 37·6	19 26 N.	,, 3,	21 22	*m*
U Ophiuchi... ...	17 10·9	1 20 N.	,, 5,	18 29	*m*
R Scuti	18 41·6	5 50 S.	,, 8,		*m*
U Aquilæ	19 23·4	7 16 S.	,, 9,	21 0	*M*
χ Cygni	19 46·3	32 38 N.	,, 6,		*m*
T Vulpeculæ ...	20 46·8	27 50 N.	,, 9,	21 0	*m*
Y Cygni	20 47·6	34 14 N.	,, 4,	15 40	*m*
			,, 7,	15 35	*m*
δ Cephei	22 25·0	57 51 N.	,, 8,	23 0	*M*

M signifies maximum; *m* minimum.

SEISMOLOGICAL WORK IN JAPAN.[1]

THE seismological work which has been accomplished in Japan is to a great extent described in fourteen small volumes published by a Society which was organized in 1880 to study phenomena connected with earthquakes and volcanoes. This Society is called the Seismological Society of Japan. An epitome of a portion of this work is to be found in nine Reports on the volcanic phenomena of Japan issued by this Association. A glance at the first few volumes published by the Seismological Society shows that the attention of its members was directed towards seismometry. For several years attempts were made to record earthquakes by using the old types of earthquake instruments, such as columns balanced on end, bowls or tubes filled with liquid, pendulums with pencils or pointers writing on paper or smoked glass. The records obtained from instruments of this order were, however, gradually recognized as being too indefinite; the instruments indicated that shakings had taken place, but they failed to measure them. All investigators recognized that to measure the movement of the earth it was necessary, while the movement was going on, to obtain a steady point or platform relatively to which the motion might be measured. By the patient labours of investigators in Japan, which have extended over many years, this has been accomplished, and we now have pendulums and other forms of instruments which for small displacements are in neutral equilibrium, so that when the frames carrying these instruments are shaken back and forth or up and down there are certain portions of them which remain at rest. From these steady points pointers project which write the movements or magnified representations of these movements upon suitably prepared surfaces.

From the simple pendulum and style, tracing its movements in sand, and costing but a few pence, elaborate instruments, embracing many new mechanical contrivances, and writing their movements with delicate siphons on continuously running bands of paper, have gradually been evolved. With the assistance of these instruments many thousands of diagrams, each of which represents in absolute measures the back and forth motions of the ground during an earthquake, have been obtained, and we now know the true nature of earthquake movement. We have learnt that, in many earthquakes which are quite perceptible and sometimes even alarming, the amplitude of motion may not exceed a millimetre, while if it reached 25 millimetres, or an inch, we might expect cities to be ruined.

The results which have flowed from a study of these diagrams are numerous and interesting. We now know that the direction of movement in any given earthquake is continually varying. At one moment a point on the surface of the earth may be moving north and south, and the next moment it may be moving east and west, while at other times it may be following a path too intricate to be easily described.

More interesting observations relate to the period and amplitude of the earth's motion, from which may be calculated the destructive power, which depends partly on the maximum velocity and partly on the suddenness of movement. Some earthquakes commence with preliminary tremors, which have been recorded with a frequency of eight or ten waves per second.

The back and forth movements of considerable amplitude which constitute the shock or shocks in an earthquake usually have a period of one or two seconds, while the ordinary back and forth movements, constituting a greater part of the shaking that is sensible, have usually a period of from three to five per second. At the end of a disturbance the wave-period is almost always very much greater than it is at the commencement or middle of a disturbance. Quite recently an earthquake was recorded in Japan, having a period of from six to eight seconds.

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[1] A Paper, by Prof. John Milne, of the Imperial University of Japan, Tokio, read at the British Association.

Observations like this are undoubtedly valuable from a scientific standpoint, but many observations are of practical importance. For example, we now know that a seismic survey can be made of any given piece of property, and as the result of such a survey it may be found that buildings erected on one side of the given area may suffer very much more than those upon the other side. Again, we know that, because in severe earthquakes the motion at the bottom of a comparatively shallow pit is very much less than it is upon the surface, buildings may be partially cut off from earthquake motion by giving them proper foundations.

In addition to the theoretical and practical results which have flowed from the study of earthquake diagrams, mechanical science has gained something from the new types of machines that have been evolved. Now we know how to make pendulums astatic. New combinations in clockwork have been invented, new governors for machinery designed, some of which have already proved themselves useful for other purposes than earthquake machinery. One machine, which has been the outcome of seismological work in Japan, and which promises to be of practical value outside the domain of seismology, is an instrument which records the vibrations in a railway train. With diagrams of these vibrations before us, we are enabled to time a train between stations, to see when it went quickly and when it went slowly, to note the duration of stoppages, to detect irregularities on a line, as, for instance, those which may occur at crossings and points, those due to a want of ballast, variations in gauge, imperfections in bridges, &c.

Seismometrical observations have not alone been confined to the observation of earthquakes proper, but observations have been made upon disturbances produced by explosions of substances like dynamite and gunpowder, the falling of heavy weights, and the moving of trains, &c. The records obtained from these experiments have perhaps taught us more about the nature of earth vibrations than we have obtained from the observation of actual earthquakes. So far as surface disturbances in superficial soil are concerned, we now know that the phenomena they present are anything but what we might anticipate as likely to occur in a theoretically elastic material.

An extremely practical subject which has received attention in Japan has been observations and experiments upon the effects produced by earthquakes upon buildings; an account of them—many of which have been successfully put into practice by builders—is now being published as the fourteenth volume of the Seismological Society's Transactions. As this particular subject is of such vital importance to the Government of Japan, who are continually erecting European structures, it is at the present time being discussed by a Committee of engineers, architects, and others, summoned for the purpose by the late Viscount Mori, Minister of Education.

The Imperial Government of Japan, by establishing in the Meteorological Department an Earthquake Bureau, and in the Imperial University a Chair of Seismology, have given an impetus to seismological investigation in general. In several parts of the country seismographs have been established, and, at between 600 and 700 stations, records are kept of all disturbances which are felt. From these records we are now able to study the distribution of seismic activity, both with regard to space and time. For instance, we now know that the greater number of shocks originate on or near the eastern coast; we know that there are many "centrums," from some of which weak, and from others strong, shocks originate; that, on the average, we feel in Japan at least two shocks per day.

Inasmuch as earthquake disturbances are relatively superficial, we may consider the area of disturbance as a very fair estimate of seismic effort. In 1885 the land area shaken was about 660,000 square miles, and in 1886 it was about 562,000 square miles.

Here we have the commencement of a series of interesting figures which may, perhaps, be related to a heat-gradient—to the fluctuations in the flow of the Black Stream, or to something not yet thought about.

Hitherto, when studying earthquakes in relation to meteorological changes, the position of the moon, the seasons, &c., we have been compelled to take very imperfect catalogues of shocks which have originated from "centrums" as independent of each other as most volcanoes are of each other. Now we are getting material which will enable us to study a group of earthquakes which have come from a given origin. Disturbances in the ocean have not been overlooked, and the waves which Japan has sent to America, and those which America has returned, have been carefully investigated, and average depths of the ocean along several lines have been determined. In all instances it appears that the depths calculated from the transmission of a sea-wave are a little less than the depths obtained by averaging the soundings. Does this mean that there is an incompleteness in the formulæ which have been used? or does it mean that sailors have allowed their line to run a little after striking bottom?

Other investigations which have been made relate to the effects produced by earthquakes upon the lower animals; and one investigator, Prof. Sekiya, at one time kept pheasants purposely to observe their behaviour at the time of an earthquake. A conclusion arrived at is that pheasants, geese, horses, and other animals often show decided symptoms of alarm a few seconds before the occurrence of a severe shaking. The reason of this probably is that they are more sensitive to preliminary tremors than human beings.

The relationship between volcanic phenomena, earth currents and magnetism, and earth disturbances, has not been unnoticed, while mathematicians and physicists have had new problems suggested to them respecting the determination of earthquake origins, the depth of "centrums," the force required to cause destruction like the shattering and overturning of structures, the propagation of surface waves, &c.

The observations of late years respecting the destruction of submarine cables have led Mr. Forster, of Zante, to the opinion that certain earthquakes are the immediate result of submarine landslips, and suggested to Japanese observers that something might be learnt by periodical soundings made along the Japanese shores. Volcanoes have not been overlooked, and many new facts have been obtained for vulcanologists. For instance, we now know that many volcanoes have a definite curvature dependent upon the density and strength of the materials of which they are built, and given any two of these three quantities—curvature, density, and strength—we may determine the third; thus, as pointed out by Mr. Becker, of the United States Geological Survey, may not the shape of lunar volcanoes, with an assumption as to the density of the material of which they are composed, lead to an opinion as to the materials out of which they are made?

About the extremely minute movements called earth tremors, which are probably in all places and at all times to be observed, much has been done. For three or four years, by a specially-contrived instrument, these have been recorded automatically. The investigation of these records has led to the conclusion that earth tremors are closely connected with wind. When a heavy wind is blowing, tremors are usually strongly marked, but the more curious result is that they are often very marked in calm weather. An inspection of the tri-daily weather maps published in Japan shows that on these occasions a heavy wind is blowing against high mountains 60 to 200 miles distant. From this it appears that earth tremors outrace storms inland, much in the same way that small waves outrace storms upon the ocean. Insomuch as earth tremors accompany heavy barometrical gradients, and these are related to the outpouring of fire-damp in our mines, it would appear a legitimate investigation to study the behaviour of a tromometer, say in the Newcastle area, in relation to the escape of underground gas. Hitherto I believe that investigators in Great Britain have been observing seismometers rather than tromometers.

With these few remarks respecting the general nature of investigations which have been made and are yet going on in Japan, I will enumerate a few phenomena which require explanation, and suggest a few investigations which have yet to be undertaken.

Large earthquakes are usually preceded by a series of short-period vibrations. These vibrations have an amplitude of about one-tenth of a millimetre, and six to ten of them occur per second. With a seismograph giving great multiplication, it is probable that still smaller and more rapidly recurring waves may be recorded. These hitherto unseen portions of an earthquake may be the cause of the sound-phenomena of earthquakes, and the movements which, although not felt by human beings, alarm the lower animals. Why are the larger movements of an earthquake preceded by tremors of this description?

The rate at which earthquake motion is propagated is sometimes very high. From Toronto to Ontario in the Charleston earthquake of 1886 the velocity was over 15,000 feet per second, whilst at the destruction of Flood Rock, in 1885, velocities of 20,000 feet per second were observed.

As was suggested by Sir William Thomson, observations like these may mean that the rigidity of the Earth is greater than that of surface rocks. If it is so, then, as Sir William suggested, extended observations may lead to the determination of these rigidities. In connection with this, it must be remarked, that, both for artificial as well as for natural disturbances, the velocity of transmission varies with the intensity of the initial disturbance, the nature of the medium, and it becomes less as a disturbance radiates. General Abbot, however, in one instance noted an increase in velocity as a disturbance radiated.

What is perhaps closely connected with the above, or what at least is analogous, is the fact that at a given station the wave-period becomes longer as a disturbance dies out, and it also becomes longer as a disturbance radiates. One inference to be drawn from this may be that long-period earthquakes originate at a distance, a wave flattening out as it radiates, pretty much as it does in the ocean; but Sir William Thomson has suggested that a long-period disturbance may be related to the dimensions of the focal cavity. Recently, in Tokio, an earthquake having a period of about eight seconds was observed. For seismographs to record this, they must have been tipped from side to side.

Another point of interest is that for *small* displacements period increases with amplitude, but after a certain amplitude is reached the period is either constant or only increases very slowly. This observation apparently harmonizes earth motions with those of ideally elastic bodies.

Another set of interesting observations is the relationship between normal and transverse movements. At a short distance from an origin the normal movement distinctly outraces the transverse motion, but when the amplitude of the normal motion has been decreased until it practically equals that of the transverse motion the separation between the movements is *nil*. A curious feature, especially in normal movements, is the fact that near an origin the movement inwards or towards the source of the disturbance is greater than it is outwards; further, as a normal wave radiates it may be observed to gradually break up into two waves, in consequence of which a diagram taken at one station may be very different from one taken at another.

In conclusion, I will point out a few observations which, on account of the expense they involve, the difficulty of obtaining observers, &c., have not, or at least only partially, yet been undertaken:—

1. *Velocity of Earthquake Propagation.*

The importance of determining the velocity of earthquake propagation has already been noted, and it has been shown that on account of the difference in the aspect of diagrams at neighbouring stations it cannot be done on a small area. The Imperial Telegraph Department of Japan is at the present moment giving its assistance in this matter, but as so much depends upon telegraph operators who have duties to attend to, a number of specially constructed timepieces are required.

2. *A Gravity Observatory.*

Many years ago Sir William Thomson suggested the importance of an observatory to determine whether there are changes in the value of G. In Japan we have a country where superficial and probably subterranean and suboceanic changes are taking place very rapidly. Last year the greater portion of a mountain was blown away, and an area measuring 12 miles by 10 miles was, in ten minutes, or less, buried from 30 to 100 feet beneath a stream of earth and rock. What is going on beneath our volcanoes we do not know, but every now and then they pour out volumes of solid matter. Along the coast we have a sharp and deep depression, perhaps the deepest on the face of the globe. Do submarine landslips take place along this coast, as they most certainly have done in other parts of the world?

Lastly, may there not be an apparent change in the value of G, dependent upon the time at which the observations have been made? At certain seasons tremor storms are very marked, and may not their minute movements have a cumulative effect upon the small swings of pendulums used in gravity determinations. Pendulum observations of the ordinary kind have been made in many parts of Japan, from the summit of Fujiyama to the Bonin Islands, but neither in Japan nor in any other portion of the world—so far as the writer is aware—has a pendulum been swung at a given point for a considerable period of time.

3. *Observations on Submarine Changes.*

Many of the Japanese earthquakes originate near the deep submarine depression which has been spoken about. If any of these are due to suboceanic land slides or sinkings, as have been observed in the Mediterranean and in the Atlantic, such changes might be noted by periodical soundings, and perhaps even by the records of tide-gauges.

4. *Magnetic Observations.*

Dr. Edmund Naumann called attention to the fact that near certain Japanese volcanoes there have been abnormal changes in declination. The volcanic rocks of Japan are exceedingly magnetic, and they are of enormous extent. Many of the rocks in Fujiyama will deflect an ordinary compass needle through 180°. Now, as these rocks are sometimes hot and sometimes cold, whilst at the time of an eruption, and possibly at other times, there are subterranean shiftings in the positions of these magnetic masses, could not these changes be noted by establishing a magnetic observatory on the side, say, of a recent volcano like Fujiyama?

5. *Bending of the Earth Crust due to Tidal Load.*

Some years ago, in conjunction with Mr. John Stoddart, Manager of the Takashima Colliery, the workings of which extend a considerable distance beneath the Pacific Ocean, the writer, by means of a simple apparatus, endeavoured to measure any movement of the roof of the mine which might be occasioned by the rise and fall in the tide. Unfortunately, the apparatus together with other instruments were lost by a complete subsidence in one portion of the workings, and these observations, if they are of any value, have to be recommenced.

6. *Tromometric Observations.*

A continuous automatic observation of earth tremors has hitherto only been made in Tokio. Might not these observations be continued in a coal-mining region to determine whether these minute earth movements, which are certainly connected with barometrical changes, hold any relation to the outflow of fire-damp.

7. *Earth Currents.*

Have earth currents any relationship to earth tremors and to earthquakes? Earth currents are produced when the ground is shaken by an explosion of dynamite, but this might be due to the increase or diminution of pressure in the earth plates causing changes in chemical activity. Have earth currents been observed in the vicinity of an active volcano, or in relation to some large earth fracture?

8. *Earth Oscillations.*

In Japan the borings of marine shells, 10 or 12 feet above high-water mark, in very soft rock which easily disintegrates, shows that there has been a rapid movement in the earth's crust relatively to sea-level. Is it likely that this could be measured, and the axis of the movement be determined, by repeating, at intervals of twelve months, the levelling of two lines running as nearly as possible at right angles to each other? It has been suggested that, if the movement is rapid, say 1 inch per year in a large bay like that of Tokio when the rise and fall of the tide is small, the isochronous observation of records obtained under approximately similar conditions from a series of tide-gauges, the level at each gauge relative to some fixed point on the neighbouring rocks being known, might furnish data which would be of value in the measuring of earth oscillations.

These, then, are a few suggestions respecting work which might perhaps be better carried out in Japan than in most other countries. They are laid before this meeting for the purpose of obtaining an opinion as to how far they may be regarded as legitimate subjects for investigation; and if the members of the meeting will freely criticize them, or suggest other lines of research, a benefit will be conferred upon workers in Japan, and on all who are interested in earth physics.